Angiographic Results in Intracranial Aneurysms Treated with Inert Platinum Coils

J.R. VANZIN[1], C. MOUNAYER[2], D.G. ABUD[3], R. D'AGOSTINI ANNES[4], J. MORET[5]

[1] *Interventional Neuroradiology, Neurology and Neurosurgery Service; Passo Fundo, Brazil*
[2] *Interventional Neuroradiology, Service de Neuroradiologie Interventionnelle, Hôpital Dupuytren; Limoges, France*
[3] *Interventional Neuroradiology/Vascular and Interventional Radiology, Hospital das Clínicas - Ribeirão Preto School of Medicine, University of São Paulo; São Paulo, Brazil*
[4] *Neurosurgery Resident, São Vicente de Paulo University Hospital; Passo Fundo, Brazil*
[5] *Interventional Neuroradiology, Service de Neuroradiologie Interventionnelle, Hôpital Beaujon; Paris, France*

Key words: intracranial aneurysms, endovascular procedures, therapeutic embolization, cerebral angiography, recurrence

Summary

This study was designed in an attempt to identify the risk factors that could be significantly associated with angiographic recurrences after selective endovascular treatment of aneurysms with inert platinum coils. A retrospective analysis of all patients with selective endovascular coil occlusion of intracranial aneurysms was prospectively collected from 1999 to 2003. There were 455 aneurysms treated with inert platinum coils and followed by digital subtraction angiography. Angiographic results were classified according Roy and Raymond's classification. Recurrences were subjectively divided into minor and major. The most significant predictors for angiographic recurrences were determined by ANOVAs logistic regression, Cochran-Mantel-Haenszel test, Fisher exact probability. Short-term (4.3±1.4 months) follow-up angiograms were available in 377 aneurysms, middle-term (14.1±4.0 months) in 327 and long-term (37.4±11.5 months) in 180. Recurrences were found in 26.8% of treated aneurysms with a mean of 21±15.7 months of follow-up. Major recurrences needing retreatment were present in 8.8% during a mean period follow-up of 17.9±12.29 months after the initial endovascular treatment. One patient (0.2%) experienced a bleed during the follow-up period. Recurrences after endovascular treatment of aneurysms with inert platinum coils are frequent, but hemorrhages are unusual. Single aneurysm, ruptured aneurysm, neck greater than 4 mm and time of follow-up were risk factors for recurrence after endovascular treatment. The retreatment of recurrent aneurysm decreases the risk of major recurrences 9.8 times. Long-term angiogram monitoring is necessary for the population with significant recurrence predictors.

Introduction

Endovascular therapy with platinum coil has been performed with success since the early 1990s as an alternative to surgical clipping [1-4] and nowadays this technique is currently used [5-7]. The goal of intracranial aneurysms treatment (whatever the technique – surgical or endovascular) is to completely isolate the aneurysmal sac from the normal cerebral circulation. Randomized studies comparing endovascular and surgical approaches of intracranial aneurysms have shown better clinical outcomes for the group of patients treated by embolization of the aneurysmal sac with platinum coils [8,9].

Unfortunately, the endovascular technique was found to be less definitive than surgical clipping, due to the high rate of long-term angiographic recurrences [10,11]. The mechanisms involved in the recurrences of aneurysms have not been well determined yet [12,13]. Due to this limitation of the coiling technique, long-term monitoring imaging protocols have been estab-

lished to follow the angiographic evolution of the embolized aneurysms [14,15]. Many factors have been implicated in the mechanism of angiographic recurrences after coil embolization. Among them: treatment after acute rupture, aneurysm size, incomplete angiographic occlusion [11], and the embolized volume of the aneurysm (volume of coils/volume of the aneurysmal sac) [16,17].

New embolic devices have been proposed to increase the long-term efficacy of endovascular treatment, such as bioabsorbable polymers [18-20], hydrophilic polymer coils [21-23], and liquid agents [24,25]. However, there might be a need to identify a population with characteristics that lead to a higher risk of recurrence, or, contrarily a subpopulation of patients in whom recurrences are unlikely.

This study was designed in an attempt to identify the risk factors that could be significantly associated with angiographic recurrences after selective endovascular treatment of aneurysms with inert platinum coils.

Materials and Methods

Patient Population

All patients with intracranial aneurysms treated by endovascular treatment with detachable coils, between January 1999 and December 2003, were revised.

The data collection was retrospectively obtained by extensive medical records review. There were ruptured and unruptured lesions. There were strict inclusion criteria. Selective endosaccular platinum coil occlusion was performed in 549 patients with 638 aneurysms. No alternative device was accepted except remodeling technique and inert platinum coils. Out of these patients, 34 patients died (5.5%) (one patient with two aneurysms), 32 patients had ruptured aneurysms and two had unruptured lesions. One hundred and forty patients with 148 aneurysms (21.9%) were not controlled. The main reason for exclusion was a planned follow-up, but not yet performed, in 65 cases (10.2%), followed by 59 (9.2%) aneurysms controlled in other institutions (without the same working projections), and patients were lost – 14 (2.2%) or refused – ten (1.6%) the follow-up. Finally, a total of 391 patients with 455 aneurysms were treated and controlled and were the subjects of this study.

Demographic Data

The demographic data included age, sex, history of subarachnoid hemorrhage (SAH) or not, presence of multiple aneurysms, treatment during early or late phase after SAH, and Hunt and Hess grades at the time of treatment. Out of 391 patients followed, the mean±SD age was 48±12.8 years (15 to 91 years) and 68.3% of patients were women. The mean±SD age of female patients was 48±13.2 years and the mean±SD age of male patients was 49±12.1 years. The majority of patients with ruptured aneurysms were treated in the acute phase (95.8%). The Hunt and Hess grades at the time of treatment in the ruptured group were grade I-II in 61.3%, grade III in 22.6% and IV-V in 16.1%. Patients presented multiple aneurysms in 115 cases with a total of 154 lesions (29.4%). Out of those, 132 aneurysms were treated by endovascular technique or by surgical clipping of other lesions at different times or not. Some lesions were not treated because they were considered to be very small and they were angiographically followed up. Out of the aneurysms treated by endovascular approach, one aneurysm was found in 340 patients; two aneurysms in 39 patients; three aneurysms in 11 patients; and four aneurysms in one patient.

Endovascular Treatment

All 455 aneurysms included in this study were treated exclusively with inert platinum coils. Four brands of coils were used: Guglielmi detachable coils (GDC; Boston Scientifics/Target, Fremont, CA, USA), Sapphire (Micro Therapeutics Inc., Irvine, CA, USA) and its earlier models (Dendron GmbH, a subsidiary of Micro-Therapeutics, Inc, Bochum, NRW, Germany), Microplex (Microvention, Aliso Viejo, CA, USA) and Trufill DCS detachable coil (Cordis, Miami Lakes, FL, USA). The combination of more than one brand during the endovascular treatment was frequently applied, usually based on the experience of the endovascular surgeon concerning shape and softness. In total, 2,692 coils were used, varying from one to 29 coils per aneurysm with a mean±SD of 5.9±4.76 coils per aneurysm. Balloon-assisted coil embolization (remodeling technique) was performed in 168 cases (36.9%), 107 cases being for unruptured aneurysms and 61 cases for ruptured aneurysms. Most aneurysms were treated only once (98.9%), 0.9%

were treated twice and 0.2% three times to obtain a satisfactory angiographic result. Patients with failure of coil embolization were sent to surgical clipping or a parent-vessel occlusion was performed when it was possible and they were excluded from this study. Patients with major recurrence were most often re-treated with coiling (99.8%). Only one patient was re-treated by surgical clipping. A total of 510 endovascular procedures were performed during the four years of the study, including retreatments.

Aneurysmal Characteristics

Aneurysmal characteristics comprised the ruptured/unruptured nature of the lesion, as well its anatomical features – long axis, neck size, and location. Among the 455 intracranial aneurysms, 261 were ruptured (57.4%), and 194 were unruptured. From a total of 194 unruptured aneurysms, 56 (28.9%) demonstrated SAH from another aneurysm and 261 had a history of SAH (ruptured aneurysms). Based on the 3D reconstruction, the largest aneurysmal diameter was measured in millimeters, and classified as: small (< 7 mm), medium (7 to 12 mm), large (13 to 24 mm), and giant (≥25 mm). The mean ±SD diameter of the all aneurysmal sacs was 7±4.62 mm (2 to 70 mm), being 6.8±3.21 mm (2 to 20 mm) for the ruptured aneurysms, and 7.4±6.01 mm (2.3 to 70 mm) for the unruptured lesions. The aneurysmal neck was measured based on the optimal projections to visualize the neck of the aneurysm and classify it as small (<4 mm) or large (≥4 mm). The mean±SD aneurysmal neck was 3.6±1.64 (1 to 11.6 mm) for all patients, being 3.3±1.36 mm (1.1 to 11.3 mm) for ruptured, and 4.1±1.87 mm (1 to 11.6 mm) for unruptured aneurysms. The ratio aspect (RA) was calculated for all cases and classified in <2 and ≥2. The mean±SD RA was 2±0.76 (0.9 to 6.5) for all patients, being 2.1±0.72 RA (0.9 to 5.2) for ruptured, and 1.8±0.76 RA (0.9 to 6.5) for unruptured aneurysms. The location was divided into: internal carotid artery (ICA); middle cerebral artery (MCA); anterior cerebral artery (ACA), vertebrobasilar system (VB). The most frequent site was ICA with 151 aneurysms (33.2%), where 81 were ruptured and 70 unruptured, followed by the ACA and MCA with 28.8% and 28.6% respectively. The less frequent site was VB system with 43 aneurysms (9.4%), 23 were ruptured and 20 unruptured.

Angiographic Results

The following data were provided by the four senior interventional neuroradiologists of the department, they were followed at least once by digital subtracted angiography (DSA). The immediate angiographic results and the follow-up was obtained by any one of these four interventional neuroradiolgists, meaning that angiographic assessment was not necessarily performed by the physician who initially was responsible for the endovascular procedure. A blinded review was performed by the first author and if a different answer was found a new review was done together with one senior. The last patient included in this study was in December 2003, permitting at least a four-year-angiography follow-up. The degree of occlusion post embolization was classified according to Roy and Raymond [34]: class I meaning complete occlusion; class II, residual neck and class III, residual aneurysm. Recurrence was defined when there was any growth of angiographic opacification of the aneurysm previously treated, or when any change in class (I→II, I→III, or II→III) occurred and they were classified in minor and major. The classification of minor recurrence was applied when an aneurysmal neck or sac showed growth at the time of any angiographic control and this modification remained unchanged in the subsequent angiograms, also when the recanalization could not permit any retreatment. Major recurrence was considered when the growth of the aneurysmal neck or sac evolved, changing more than 2 mm in the subsequent follow-up angiograms, and would allow (theoretically) a retreatment with coils. All the aneurysms with major recurrence in our series were retreated. The number of months between treatment and the first follow-up angiogram showing the recurrence was analyzed.

Angiographic Follow-up

The protocol of angiographic follow-up after embolization was one to six months (short-term), seven to 24 months (middle-term) and more than 24 months (long-term). Angiographic follow-up consisted in antero-posterior, lateral and the same working projections used at the time of the treatment, which were determined according to the patient's bony landmarks defined during the endovascular procedure. Some patients had more than one control during each

follow-up, especially patients with multiple aneurysms. Our protocol only considered DSA for evaluation of the aneurysmal evolution over time. Short-term follow-up angiograms were available in 377 aneurysms, medium-term in 327 aneurysms, and long-term in 180 aneurysms for a total of 885 angiograms evaluated in a total period of 12,973 months of follow-up (mean 21±15.7 months). Additional clinical data were collected for each patient during hospitalization for DSA follow-up or when it was not possible by telephone interview. New neurological episodes or rebleeding were recorded. The total number of months of angiographic follow-up for each patient was recorded. The mean clinical follow-up was 39.21 months.

Statistical Analysis

The data were analyzed in SAS (version 8.2) and the most significant predictive data of angiographic recurrence were determined by using logistic regression, ANOVAs for quantitative variables, Cochran-Mantel-Haenszel test for semi-quantitative variables, Fishers'exact probability for dichotomies and X^2 test for parameter-free. When two or more aneurysms were present in the same patient, they were considered separately for statistical evaluation. Aneurysmal dimensions and time were studied as continuous variables. These variables were also analyzed by groups (size of aneurysmal sac: small, medium, large, and giant aneurysms; size of neck: small and large; and RA: <2 and ≥2). Patients were also subdivided into three groups according to the duration of angiographic follow-up: short-term included aneurysms with one to six months of angiographic follow-up; medium-term were aneurysms with seven to 24 months; and long-term were those with more than 24 months. The significant P value considered was 0.05.

Results

Angiographic Results

Most aneurysms were controlled once or twice; 153 aneurysms had only one control, 158 aneurysms had two controls and 144 aneurysms had three to five controls (total of 885 studies for 455 aneurysms). Neurological complications during the follow-ups occurred in two patients (0.2% of the follow-ups and 0.4% of patients). The mean follow-up was 2.1 angiograms by aneurysm in the group studied and 3.2 angiograms in the group retreated. The degree of aneurysmal occlusion achieved by endovascular coil embolization at the end of the procedures and during the follow-up angiograms is presented in Table 1. Short-term angiographic evaluation was performed in 377 cases (82.8%) during a total of 1,526 months (mean of 4.3±1.4 months). Medium-term angiographic follow-up was performed in 327 aneurysms (71.9%) out of the 455 aneurysms followed in a total of 4,755 months (mean of 14.1±4.0 months). Long-term angiographic follow-up was performed in 180 aneurysms (39.6%) in a total of 6,696 months (mean of 37.4±11.5 months). Eight ruptured aneurysms with class III at the end of the procedures and stable angiographic follow-up were submitted to a complementary treatment until three months after the first procedure.

Recurrences

Recurrences were found in a total of 122 among the 445 cases (26.8%) of treated aneurysms with a mean of 21±15.7 months of follow-up. Most cases of recurrence occurred in the first six months of follow-up (Figure 1). The mean±SD of months between treatment and follow-up showing recurrence was 11.2±11.15 months (one to 72 months). In the

Table 1 **Angiographic class during overall angiograms control.**

	Initial Results No. (%)	Short Term 1-6 months No. (%)	Medium Term 7-24 months No. (%)	Long Term >24 months No. (%)	n Controls
Class I	346 (76.1)	256 (67.9)	194 (59.1)	92 (51.1)	542
Class II	94 (20.6)	98 (26)	110 (33.5)	77 (42.8)	285
Class III	15 (3.3)	23 (6.1)	24 (7.3)	11 (6.1)	58
Total	455 (100)	377 (82.8)	328 (72.1)	180 (39.6)	885

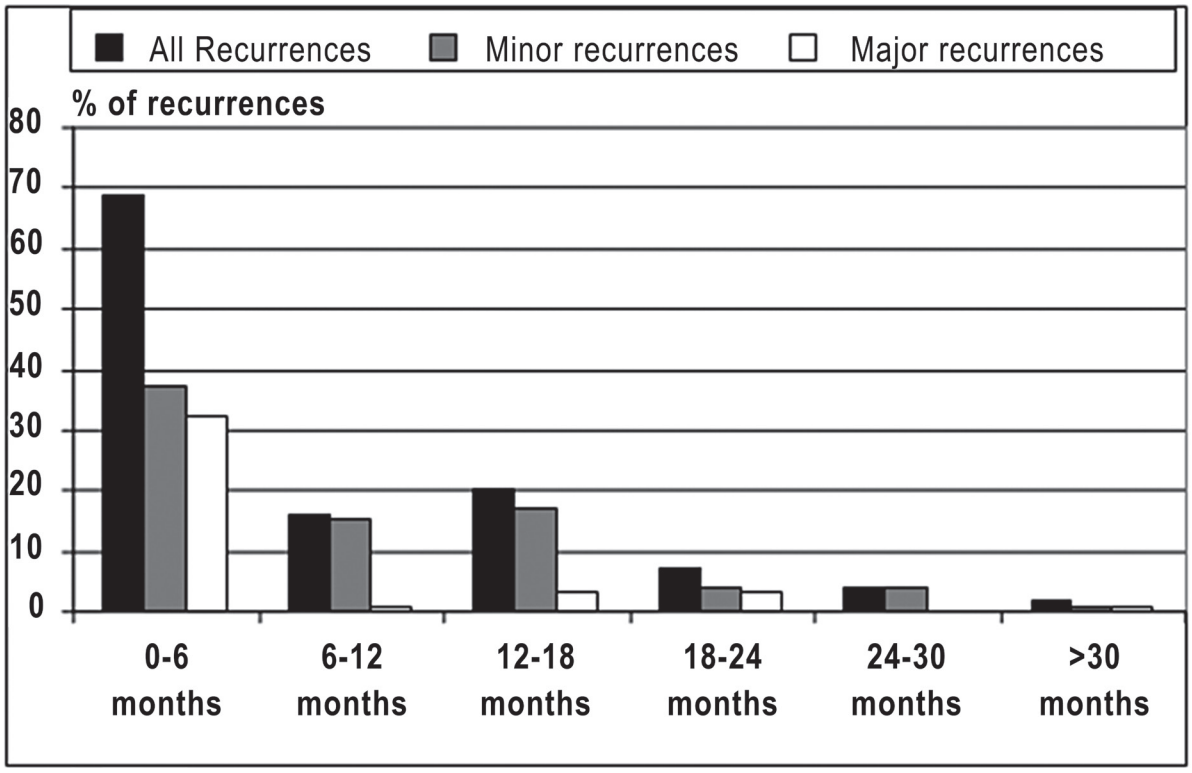

Figure 1 Recurrences of treated aneurysms in the follow-up.

group of minor recurrences, the mean±SD to develop and stabilize the recurrence after the treatment was of 25.7±16.48 months. It was 31.6±15.77 months for major recurrences. Forty aneurysms (8.8%) were retreated during a mean period follow-up of 17.9±12.29 months after initial endovascular treatment. Eleven aneurysms showed a second recurrence which appeared after a mean follow-up of 13.2±7.44 months. Seven aneurysms presented a minor re-recurrence and four major re-recurrences. A new retreatment was performed in these cases (mean follow-up of 8.4±4.82 months). One patient (0.2%) experienced a bleeding episode during the follow-up period (45 months after your treatment). Complete occlusion was observed in 330 aneurysms (74.3%) and 122 of those presented recurrences (26.8%), minor in 18% and major in 8.8%. After all retreatments, the rate of complete occlusion increased for 354 (77.8%). For this group minor recurrences stayed stable (20.2%) and major recurrences decreased considerably (0.9%). The retreament of recurrent aneurysms decreased 9.8 times the risk for major recurrence. Final angiographic results, stability and class changing during the study can be seen in Table 2.

Table 2 **Angiographic results and recurrence.**

	Angiography Results (before any retreatment) No. (%)	**Final Results (after overall retreatment) No. (%)**
Complete Occlusion	330 (72.5)	354 (77.8)
Incomplete Occlusion	3 (0.7)	5 (1.1)
Minor Recurrence	82 (18)	92 (20.2)
Major Recurrence	40 (8.8)	4 (0.9) P<0.001

Factors Associated with Recurrences

Age (p=0.149), sex (p=0.328), treatment during period of angiographic vasospasm (p=0.097), aspect ratio (AR) (p=0.303), balloon remodeling technique (p=0.463), and aneurysmal location (p=0.146) presented no significant influence on recurrences. The size and immediate angiographic results proved a significant risk factor for recurrence in the univariate analyses, however when analyzed by multivariate logistic regression, they were not significant. According to appropriate analysis (logistic regression), the most significant predictors of recurrence in the overall group were acutely ruptured aneurysms (p=0.032), populations with single aneurysms (p=0.024), neck size (p=0.003), and length of follow-up period (p<0.0001). The analysis of the recurrences and nature of lesions are summarized in Table 3. Comparing the populations of patients with single and multiple aneurysms, we identified that the group with single aneurysms were most susceptible to recurrences (p=0.024) (Table 4). Aneurysms with necks wider than 4 mm had a significantly higher risk of developing a recurrence (p=0.003) (Table 5). The patients were divided into three groups according to the length of angiographic follow-up; the six-month-controlled group was at lesser risk of showing a recurrence compared to the two groups with longer follow-up (seven to 24 months and 24 months or more). The recurrence rate increased according to time of follow-up (Table 6). Significant factors predicting the risk of developing any type of recurrence and studied by logistic regression are summarized in Table 7.

Table 3 **Recurrences and nature of lesions.**

	Recurrence No. / n (%)	**p-value**	**Minor n (%)**	**Major n (%)**	**p-value**
Ruptured	261 / 80 (30.6)	0.032	55 (21)	25 (9.6)	0.090
Unruptured	194 / 42 (21.6)		27 (13.9)	15 (7.7)	

No. - number of aneurysms analyzed
n - number of recurrences aneurysms

Table 4 **Population with single and multiple aneurysms.**

	Recurrence No. / n (%)	**p-value**	**Minor n (%)**	**Major n (%)**	**p-value**
Single	276 / 88 (31.9)	58 (21) 0.024	30 (10.9)	0.009	
Multiple	179 / 34 (19)		24 (13.9)	10 (5.6)	

No. - number of aneurysms analyzed
n - number of recurrences aneurysms

Table 5 **Recurrences and neck size of aneurysms.**

	Recurrence No. / n (%)	**p-value**	**Minor n (%)**	**Major n (%)**	**p-value**
Neck					
Small	311 / 72 (23.2)	0.056	55 (17.7)	17 (5.5)	0.003
Large	144 / 47 (32.6)		24 (16.6)	23 (16)	

No. - number of aneurysms analyzed
n - number of recurrences aneurysms

Discussion

The most important mechanism of aneurysmal exclusion by endovascular treatment is the deployment of platinum coils in an aneurysm through an endovascular microcatheter. When the aneurysm is densely packed with coils thrombosis occurs, excluding the aneurysm from the circulation [26]. Some authors propose that a complete isolation from the cerebral circulation and an established occlusion depends on two synchronous phenomena that occur at the level of the provisional matrix provided by clotting. The balance between endothelial cells that attempt to restore a patent lumen with mesenchymal cells invading the provisional fibrin matrix to secrete collagen [27-32]. This endothelial response is probably one of the main factors involved in the recanalization of aneurysms.

The angiographic results of the aneurysms treated by endovascular approach show that the first recanalization signals appear prematurely in the first six-month follow-up [11], which was been observed in this study. Blood circulation in the net coils permits neointimal formation in the free space of the coil surface that impede complete blood clot organization in the intrasaccular space [33].

In this study, following the patients in a time line, we noticed that two distinct groups appeared. One that evoluted progressively to major recanalization and another that remained with stable angiographic results. Many aneurysms demonstrated very small angiographic recurrence in the neck as a remodeling of the artery wall. This new angiographic aspect found repeatedly in the post-treatment angiographic control can be considered a new anatomy of the arterial lumen [34]. This new anatomy of the parent vessel remained stable despite the successive angiographic controls. The stability rate of the aneurysmal occlusion found during this study after all treatments, strongly suggests the hypothesis of the new anatomy of the arterial lumen. No hemorrhage or evolutive angiographic alteration case were found in this population.

However, in the other population, we observed that the recurrence of intracranial aneurysms is progressive. The angiographic follow-up time is undoubtedly the main factor of recanalization and the more we follow the aneurysms over time, the more recurrences we will find. Still, time is an unchangeable and inevitable factor. Neck size was another important factor involved in the recurrence of aneurysms. A small neck was more frequently associated with minor recanalization (17.7%) and stability

Table 6 **Length of follow-up period and recurrences.**

	No.	Recurrence No. / n (%)	p-value	Minor n (%)	Major n (%)	p-value
1 to 6 months	104	7 (6.7)		5 (4.8)	2 (1.9)	
7 to 24 months	172	41 (23.8)	<0.001	34 (19.8)	7 (4.1)	<0.001
> 24 months	179	74 (41.3)		43 (24)	31 (17.3)	

No. - number of aneurysms analyzed
n - number of recurrences aneurysms

Table 7 **Logistic regression on overall recurrences.**

	p-value
Single aneurysm	0.003
Ruptured aneurysm	0.028
Neck ≥ 4	0.024
Size ≥ 10	0.16
Immediate angiographic result	
Class I	0.705
Class II or III	0.051
Time of follow-up (months)	<0.001

of recurrence. An interesting fact observed in this study was that the size of the aneurysm did not influence the recurrence rates.

All new embolic materials and assisted embolization were excluded, except balloon remodeling technique, because it is retrieved after coiling. This technique was important in immediate angiographic results but did not influence recurrence.

An unpublished finding stated that populations with a single aneurysm were more susceptible to recurrences than those with multiple aneurysms (p=0.024). For the major recurrences the difference was almost twice superior, 10.9% to 5.6% (p=0.009). These results were also confirmed by logistic regression (p=0.003). This population comprised either ruptured or unruptured aneurysms. Probably the physiopathologic mechanism of the genesis of single intracranial aneurysm recurrences is not the same as those involved in multiple aneurysms and subpopulations of patients with different behavioral aneurysms may exist.

The recanalization rate of ruptured aneurysms was superior in almost 10% compared to unruptured aneurysms.

When we analyzed the retreatment, the majority of retreated aneurysms were completely excluded at the end of embolization (92%). The stability of retreated aneurysms was reached in a greater number of cases (87.5%). Despite this, new recurrences were observed, almost all of them minor, and the risk of major recurrences decreased considerably (p<0.001).

The effect of packing on the stability of embolized aneurysms remains controversial [16,17,35,36], but unfortunately, as a retrospective study, these measurements were not available for systematic review.

Rerupture of aneurysms treated by either coil embolization or surgical clipping has rarely been described after the first year [37]. Late retreatment is common after coil embolization, and very poorly studied by surgical groups, and the complication rates for endovascular retreatments are low [38]. Thus, late events are unlikely to overwhelm differences between procedures at one-year follow-up [39]. The ISAT study identified any risk factors for late retreatment after EVT: younger age, larger lumen size, and incomplete occlusion [15]. Rebleeding rates overall were not statistically different between the two treatment cohorts (three of 1012 versus seven of 1096; p=0.3), aneurysm retreatment did not cause significant additional morbidity and the data indicate that successful additional coiling decreases the risk of rebleeding [15]. The benefits of the endovascular technique continued for a period of seven years with a lower annual risk of death compared to clipping (p = 0.03) and a slightly increased annual risk of rebleeding, but was not statistically significant (p = 0.22) [40].

The CARAT Study 2008 showed that the degree of occlusion of the aneurysm is a strong predictor of subsequent risk of rupture in patients with subarachnoid hemorrhage, the goal of the endovascular treatment of intracranial aneurysm being to achieve complete occlusion [41]. Recently, the ISAT Study 2009 showed that the risk of death in five years was significantly lower in the coiled group compared to the clipped group [6].

Several criticisms about recurrence have been made for endovascular treatment compared to clippling; however, not all clipped aneurysms are controlled. The interventional neuroradiologists perform angiographic controls as routine. Angiogram control of clipped aneurysms is not an adopted routine in several neurosurgery services, and even when performed, they are almost never done in the long term. Wermer et al. showed that in patients who had recovered to an independent state after an episode of aneurysmal SAH and in whom all detected aneurysms were treated by means of clipping, the risk of a recurrence in the first ten years after treatment is 22 times higher than the risk of SAH in a healthy cohort of comparable age and sex [37]. Kivisaari and Hernesniemi published in 2004 that even after surgery by experienced neurosurgeons, neck remnants are found in nearly 10% of the cases [42]. This point is important in the discussion about angiographic controls in patients with intracranial aneurysms treated by clipping or coiling. No trial comparing angiographic results in patients treated by coiling and clipping during long time follow-up has been designed to date.

Conclusions

Angiographic recurrences after endovascular treatment of aneurysms with inert platinum coils are frequent, but minor recurrences tend to be stable and do not a represent risk for the patients. Although the majority of these recurrences occur early during the first year, they can appear years after treatment.

Subpopulations of aneurysms with different behaviors could be considered. Single aneurysms, ruptured aneurysms, neck > 4 mm and time of follow-up were statistically significant risk factors for recurrence after endovascular treatment.

The retreament of recurrent aneurysms decreased the risk for major recurrence by 9.8 times. Stable minor recurrences which could be considered a new anatomy pattern of the parent vessel do not represent any risk of rebleeding.

Acknowledgments

We thank W. Mäkel for statistics studies and Kadija Bellahssan for secretarial assistance.

References

1 Guglielmi G, Vinuela F, Dion J, et al. Electrothrombosis of saccular aneurysms via endovascular approach. Part 2: Preliminary clinical experience. J Neurosurg. 1991; 75: 8-14.
2 Guglielmi G, Vinuela F, Duckwiler G, et al. Endovascular treatment of posterior circulation aneurysms by electrothrombosis using electrically detachable coils. J Neurosurg. 1992; 77: 515-524.
3 Guglielmi G, Vinuela F, Sepetka I, et al. Electrothrombosis of saccular aneurysms via endovascular approach. Part 1: Electrochemical basis, technique, and experimental results. J Neurosurg. 1991; 75: 1-7.
4 Moret J. Endovascular treatment of berry aneurysms by endosaccular occlusion. Acta Neurochir (Wien). 1991; 53: 48-49.
5 Hopkins LN, Lanzino G, Guterman LR. Treating complex nervous system vascular disorders through a "needle stick": origins, evolution, and future of neuroendovascular therapy. Neurosurgery. 2000; 48: 463-475.
6 Molyneux AJ, Kerr RSC, Birks J, et al. Risk of recurrent subarachnoid haemorrhage, death, or dependence and standardized mortality ratios after clipping or coiling of an intracranial aneurysm in the International Subarachnoid Aneurysm Trial (ISAT): long-term follow-up. Lancet Neurol. 2009; 8: 427-433.
7 Vinuela F, Duckwiler G, Mawad M. Guglielmi detachable coil embolization of acute intracranial aneurysm: perioperative anatomical and clinical outcome in 403 patients. J Neurosurg. 1997; 86: 475-482.
8 Molyneux A, Kerr R, Stratton I, et al. International Subarachnoid Aneurysm Trial (ISAT) Collaborative Group. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. Lancet. 2002; 360: 1267-1274.
9 Wiebers DO, Whisnant JP, Huston J, et al. International Study of Unruptured Intracranial Aneurysms Investigators. Unruptured intracranial aneurysms: natural history, clinical outcome, and risks of surgical and endovascular treatment. Lancet. 2003; 362: 103-110.
10 Cognard C, Weill A, Spelle L, et al. Long-term angiographic follow-up of 169 intracranial berry aneurysms occluded with detachable coils. Radiology. 1999; 212: 348-356.
11 Raymond J, Guilbert F, Weill A, et al. Long-term angiographic recurrences after selective endovascular treatment of aneurysms with detachable coils. Stroke. 2003; 34: 1398-1403.
12 Bavinzski G, Richling B, Binder BR, et al. Histopathological findings in experimental aneurysms embolized with conventional and thrombogenic/antithrombolytic Guglielmi coils. Minim Invasive Neurosurg. 1999; 42: 167-174.
13 Bavinzski G, Talazoglu V, Killer M, et al. Gross and microscopic histopathological findings in aneurysms of the human brain treated with Guglielmi detachable coils. J Neurosurg. 1999; 91: 284-293.
14 Byrne JV, Molyneux AJ, Chir B. Five-year experience in using coil embolization for ruptured intracranial aneurysms: outcomes and incidence of late rebleeding. J Neurosurg.1999; 90: 656-663.
15 Campi A, Ramzi N, Molyneux AJ, et al. Retreatment of ruptured cerebral aneurisms in patients randomized by coiling or clipping in the international subarachnoid aneurysm trial (ISAT). Stroke. 2007; 38: 1538-1544.
16 Sluzewski M, van Rooij WJ, Slob MJ, et al. Relation between aneurysm volume, packing, and compaction in 145 cerebral aneurysms treated with coils. Radiology. 2004; 231: 653-658.
17 Tamatani S, Ito Y, Abe H, et al. Evaluation of the stability of aneurysms after embolization using detachable coils: correlation between stability of aneurysms and embolized volume of aneurysms. Am J Neuroradiol. 2002; 23: 762-767.
18 Murayama Y, Tateshima S, Gonzalez NR, et al. Matrix and bioabsorbable polymeric coils accelerate healing of intracranial aneurysms: long-term experimental study. Stroke. 2003; 34: 2031-2037.
19 Murayama Y, Vinuela F, Ishii A, et al. Initial clinical experience with matrix detachable coils for the treatment of intracranial aneurysms. J Neurosurg. 2006; 105: 192-199.
20 Wong GK, Yu SC, Poon WS. Clinical and angiographic outcome of intracranial aneurysms treated with Matrix detachable coils in Chinese patients. Surg Neurol. 2007; 67: 122-126.
21 Arthur AS, Wilson SA, Dixit S, et al. Hydrogel-coated coils for the treatment of cerebral aneurysms: preliminary results. Neurosurg Focus. 2005; 18 (2): E1.
22 Berenstein A, Song JK, Niimi Y, et al. Treatment of cerebral aneurysms with hydrogel-coated platinum coils (HydroCoil): early single-center experience. Am J Neuroradiol. 2006; 27: 1834-1840.
23 Gaba RC, Ansari SA, Roy SS, et al. Embolization of intracranial aneurysms with hydrogel-coated coils versus inert platinum coils: effects on packing density, coil length and quantity, procedure performance, cost, length of hospital stay, and durability of therapy. Stroke. 2006; 37: 1443-1450.
24 Lubicz B, Piotin M, Mounayer C, et al. Selective endovascular treatment of intracranial aneurysms with a liquid embolic: a single-center experience in 39 patients with 41 aneurysms. Am J Neuroradiol. 2005; 26: 885-893.
25 Molyneux AJ, Cekirge S, Saatci I, et al. Cerebral Aneurysm Multicenter European Onyx (CAMEO) trial: results of a prospective observational study in 20 European centers. Am J Neuroradiol. 2004; 25: 39-51.
26 Raymond J, Venne D, Allas S, et al. Healing mechanisms in experimental aneurysms. I. Vascular smooth muscle cells and neointima formation. J Neuroradiol. 1999; 26: 7-20.

27 Furie B, Furie BC. Molecular basis of blood coagulation. In: Hofmann R, Silberstein L, Benz EJ eds. Hematology – basic principles and practice. London: Churchill Livingston; 2000. p. 1783-1804.
28 Raymond J, Desfaits AC, Roy D. Fibrinogen and vascular smooth muscle cell grafts promote healing of experimental aneurysms treated by embolization. Stroke. 1999; 30: 1657-1664.
29 Raymond J, Guilbert F, Metcalfe A, et al. Role of the endothelial lining in recurrences after coil embolization: prevention of recanalization by endothelial denudation. Stroke. 2004; 35: 1471-1475.
30 Raymond J, Leblanc P, Morel F, et al. Beta radiation and inhibition of recanalization after coil embolization of canine arteries and experimental aneurysms: how should radiation be delivered? Stroke. 2003; 34: 1262-1268.
31 Raymond J, Mounayer C, Salazkin I, et al. Safety and effectiveness of radioactive coil embolization of aneurysms: effects of radiation on recanalization, clot organization, neointima formation, and surrounding nerves in experimental models. Stroke. 2006; 37: 2147-2152.
32 Raymond J, Roy D, Leblanc P, et al. Endovascular treatment of intracranial aneurysms with radioactive coils: initial clinical experience. Stroke. 2003; 34: 2801-2806.
33 Raymond J, Sauvageau E, Salazkin I, et al. Role of the endothelial lining in persistence of residual lesions and growth of recurrences after endovascular treatment of experimental aneurysms. Stroke. 2002; 33: 850-855.
34 Moret J. Predictor for recanalization after endovascular treatment of intracranial aneurysms with platinum coils. Long term results in a series of 455 aneurysms. Presented at the 8th Congress of the world federation of interventional and therapeutic neuroradiology, Venice, Italy, October 19-23, 2005.
35 Piotin M, Spelle L, Mounayer C, et al. Intracranial aneurysms: treatment with bare platinum coils--aneurysm packing, complex coils, and angiographic recurrence. Radiology. 2007; 243: 500-508.
36 Slob MJ, van Rooij WJ, Sluzewski M. The relation between packing and reopening in coiled intracranial aneurysms: a prospective study. Neuroradiology. 2005; 47: 942-945.
37 Wermer MJH, Greebe P, Algra A, et al. Incidence of recurrent subarachnoid hemorrhage after clipping for ruptured intracranial aneurysms. Stroke. 2005; 36: 2394-2399.
38 The CARAT Investigators. Rates of delayed rebleeding from intracranial aneurysms are low after surgical and endovascular treatment. Stroke. 2006; 37: 1437-1442.
39 Slob MJ, Sluzewski M, van Rooij WJ, et al. Additional coiling of previously coiled cerebral aneurysms: clinical and angiographic results. Am J Neuroradiol. 2004; 25: 1373-1376.
40 Molyneux AJ, Kerr RS, Yu LM, et al. International Subarachnoid Aneurysm Trial (ISAT) Collaborative Group. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. Lancet. 2005; 366: 809-817.
41 Johnston SC, Dowd CF, Higashida RT, et al. Predictors of rehemorrhage after treatment of ruptured intracranial aneurysms – The cerebral aneurysm rerupture after treatment (CARAT) study. Stroke. 2008; 39: 120-125.
42 Kivisaari RP, Porras M, Ohman J, et al. Routine cerebral angiography after surgery for saccular aneurysms: is it worth it? Neurosurgery. 2004; 55: 1015-1024.

Rafael D'Agostini Annes, MD
Neurology and Neurosurgery Service
Teixeira Soares street, 640
Passo Fundo - RS - Brazil.
Tel.: + 55 54 3317 6000
Fax: + 55 54 3317 6022
E-mail: rdannes@yahoo.com.br